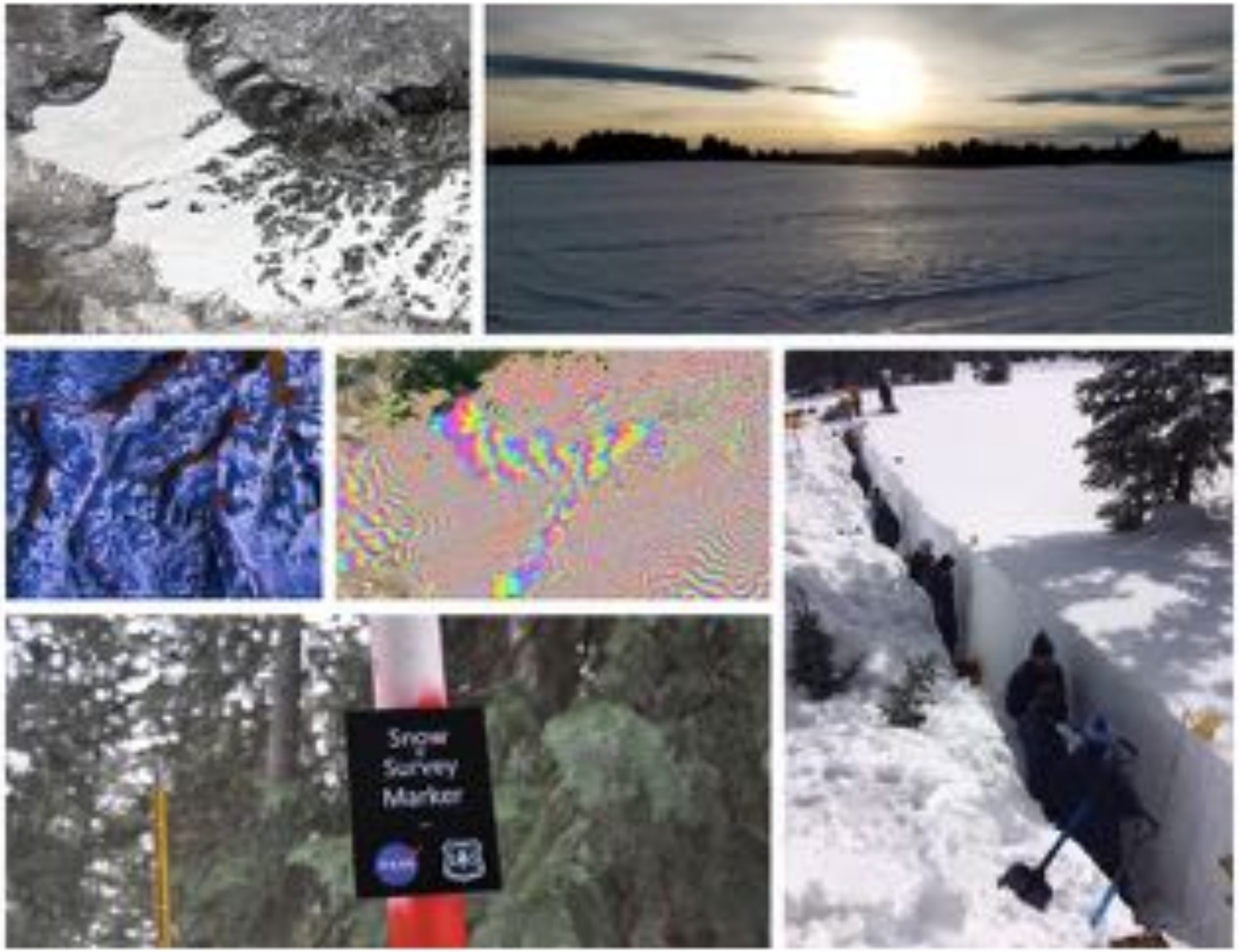
NASA SnowEx Science Plan:

Assessing Approaches for Measuring Water in Earth's Seasonal Snow



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On behalf of the Science Plan Working Group: Charles Gatebe, Ed Kim, Noah Molotch, Thomas H. Painter, Melody Sandells, and Carrie Vuyovich

SnowEx Science Plan

- **Focus**: Where are there opportunities to solve problems, better understand capabilities/limitations of our measurements, models, algorithms etc., and push things forward?
- **Purpose**: Support decision making for future SnowEx campaigns. Provide guidance to implementation teams
- **Scope**: Set priorities; implementation left to implementation team
- **Format**: Structured around articulating several “gaps”.
- **Audience**: everyone interested in SnowEx activities. Jared Entin, Jack Kaye, iSWGR, THP16, larger scientific community
- **Status:** This is a living document that seeks community input.

Identified Gaps

- Forest Snow
- Maritime Snow
- Mountain Snow
- Prairie Snow
- Snow Surface Energetics
- Tundra Snow
- Wet Snow

Images: NASA “Got Snow?” document

Identifying SWE techniques

What's missing?

Stop by the Science Plan Capabilities Chart to comment!

Table 1. Summary of snow depth/SWE and snow melt estimation techniques

		Snow Characteristic			Gap Capabilities							Space Potential		
Type	Snow sensing/ estimation Technique	Snow Depth	SWE	Melt	High-Res	Wet snow	Deep Snow	Forests	Complex Terrain	Shallow Snow	Clouds	Path to Space	Global coverage	Mature Algorithm
SWE via snow depth	Lidar	Green	Yellow	Red	Green	Green	Green	Yellow	Green	Yellow	Red	Green	Yellow	Green
	Ka-band InSAR	Green	Yellow	Red	Green	Green	Orange	Red	Green	Orange	Orange	Orange	Orange	Orange
	Dual band Ku/Ka	Green	Yellow	Red	Green	Green	Green	Red	Orange	Orange	Green	Orange	Orange	Orange
	Stereo Photogrammetry	Green	Yellow	Red	Green	Green	Green	Orange	Green	Yellow	Red	Green	Yellow	Green
	Wideband Radiometer	Green	Yellow	Red	Orange	Red	Orange	Orange	Orange	Orange	Green	Orange	Orange	Orange
volume scattering	Ku-band SAR	Yellow	Green	Green	Green	Red	Yellow	Orange	Orange	Yellow	Green	Yellow	Yellow	Yellow
	Passive Microwave	Green	Green	Yellow	Orange	Red	Red	Orange	Yellow	Green	Green	Green	Green	Green
signal interferom.	L-Band InSAR	Yellow	Green	Green	Green	Red	Yellow	Orange	Orange	Yellow	Green	Green	Yellow	Yellow
	Signals of Opportunity	Yellow	Yellow	Red	Orange	Yellow	Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
airborne / ground only	FMCW Radar	Green	Green	Red	Green	Yellow	Green	Orange	Orange	Green	Green	Red	Red	Orange
	Gamma	Yellow	Green	Red	Yellow	Green	Yellow	Yellow	Yellow	Yellow	Green	Red	Red	Green

Green – Demonstrated capability. May not work in all areas, but uncertainty is understood. May still benefit from additional research and algorithm development. TRL > 5?

Yellow – Potential capability identified and validated in multiple studies. Research needed to better quantify uncertainty. TRL 3-5?

Orange – Potential capability identified, but uncertainty not quantified. High risk. TRL 1-2?

Red – No Capability

Current Status

- Latest draft being finalized (version 1.7)

- **Impetus for revisions**
  - Incorporated feedback from the fall 2018 community survey
  - Addressed detailed reviews from 8 community members

- **Common theme**: need to further develop the role of models and data assimilation in the science plan

What modeling and assimilation questions do we need to address in SnowEx?

- We need your input and discussion!
- ~20 questions have been posed
- What more is needed? What are the priorities?

What is the minimum level of accuracy in modeled snow variables that are necessary to retrieve SWE with combined model-sensing-assimilation systems?

When and where are modeled snow variables the most and least uncertain?

How should uncertainty in modeled snow variables be estimated and utilized? Is there more utility in using a small group of robust models, or a larger ensemble of models, to characterize uncertainty?

How transferable across climates and landscape gradients are the parameters in physical snow models?

How should models treat spatial sub-grid variability?

How much vertical complexity is needed to sufficiently produce the snow variables (e.g., grain size, density) required to retrieve SWE with remote sensing?

What forcing data and downscaling approaches are ideal for minimizing snow model uncertainty?

How can detailed atmospheric and weather forecast models be leveraged for characterizing boundary conditions at the spatial resolution of model-DA systems?

What level of detail is needed in both forest / land cover data and model vegetation parameterizations to reproduce vegetation impacts on snow distribution/mass and surface energy balance variations?

How sensitive is modeled snow microstructure to characterization of the substrate below the snow cover (e.g., thawed soil, rock, surface vegetation, lake/sea ice)?

How can physical models be best utilized to fill spatial and temporal gaps in remote sensing data?

Which data assimilation approaches are most optimal for improving model accuracy, and how practical are these to implement?

Which modeled snow processes are most informed by remote sensing, and what must uniquely be estimated with models? What model states and processes can be sufficiently corrected with assimilation of remote sensing data?

How should multiple snow remote sensing observables be optimally assimilated into a model system?

How should modeled snow variables be validated in field campaigns, given differences in spatial scale, vertical resolution, and limitations in human-based measurements?

How feasible is large-scale deployment of radiance assimilation schemes to assimilate microwave brightness temperature and backscatter for SWE estimation?

How accurately must snow microstructure be modeled in radiance assimilation schemes or for retrieval schemes to estimate SWE?

How do SWE reconstruction approaches compare in various types of snow?

Is it feasible to assimilate snow albedo into snow physics models? If so, what is the best technical approach to doing so? Is an accurate radiative transfer model necessary?

Science Plan Update

Mike Durand

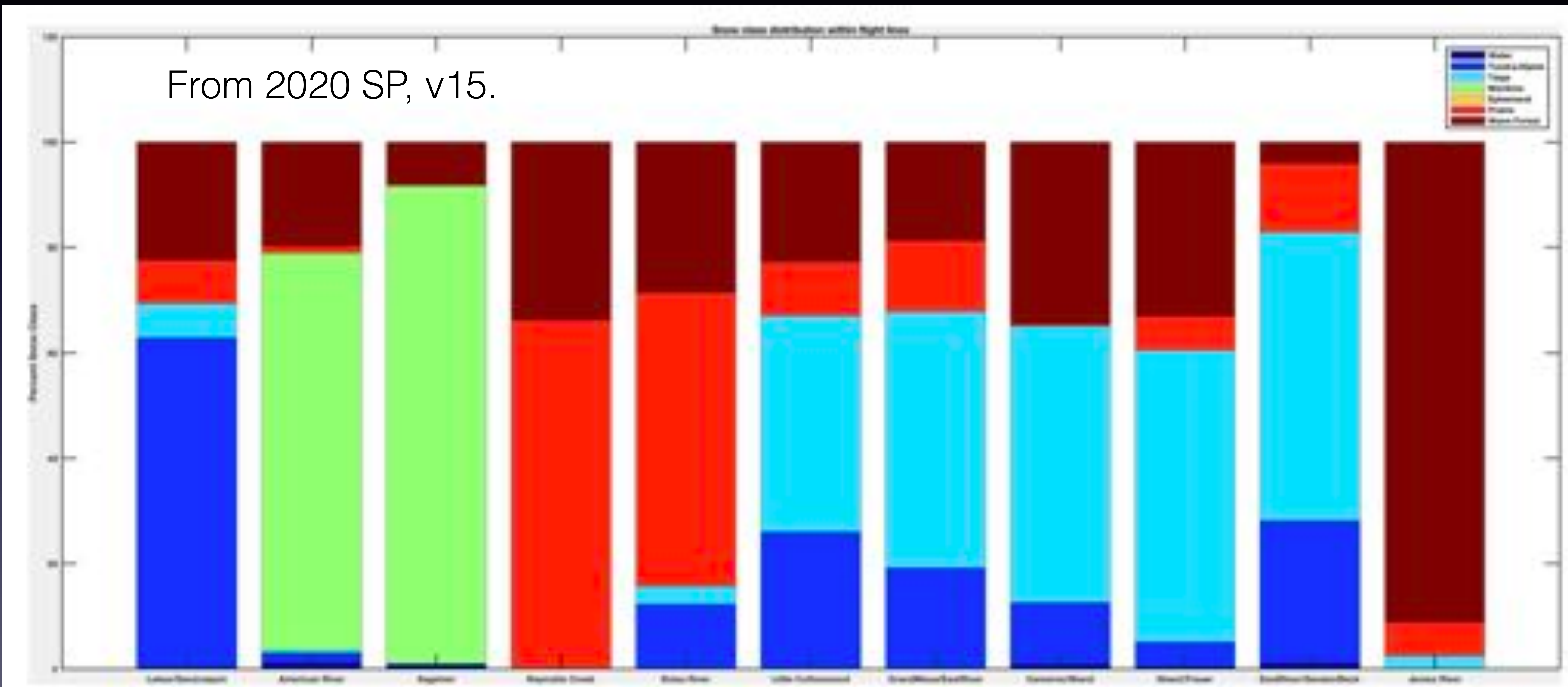
SnowEx Workshop • BWI • September 17, 2019

How well are we addressing our gaps via data acquisition?

SnowEx 2017 Grand Mesa & Senator Beck will prove invaluable for assimilation and modeling priorities: L-band, Lidar, surface temperatures, reflectance for mountain snow, and warm forest snow.

Note: Not addressing algorithm or analysis updates, just data. I want to suggest we need to switch gears to focus on data analyses to understand what’s happening with the gaps.

How well are we addressing our gaps via data acquisition?



SnowEx 2020 timeseries sites will help to close the gap and answer important questions about L-Band for mountain snow, warm forest, prairie, maritime. Key question phase ambiguities and decorrelation, and how these vary with forests. Arctic tundra & taiga not yet addressed for L-band.

How well are we addressing our gaps via data acquisition?

- A key part of the Ku retrieval problem is disentangling the snow from the substrate.

- The Grand Mesa site should help toward understanding Ku-band+passive retrievals in mountain-type snow, with some possible shallow/prairie snow in the western part of the Mesa, and the opportunity to support radiance assimilation for deep snow, elsewhere

- CSA/ECCC (Josh King, Chris Derksen, others) continue to collect amazing datasets to help unravel the Ku retrieval problem for tundra snow.

- The Ku gap will need to be further addressed in SnowEx 2021, 2022, and 2023 for taiga and prairie snow

How well are we addressing our gaps via data acquisition?

- A key part of the Ka retrieval problem is unwrapping phase in mountainous terrain, interaction with forest cover, and understanding penetration

- The Lakes & San Joaquin basin in 2020 should help elucidate this.

- Still a ways to go on this gap, especially assessment in shallow snow (prairie, tundra, etc.) where penetration will be a larger error related to total depth

Summary

- Huge strides on L-band gap expected from the 2020 datasets. Need to cover tundra & taiga

- Ku-band data will help address mountain snow and tundra snow. Need prairie snow.

- New Ka-data will help address unwrapping in mountain environments. Need shallow (tundra, taiga, prairie) snow

- Time to turn attention to how well the analyses are really closing the gaps using these data. Need to focus on modeling and assimilation approaches.